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Preliminary Results from FNAL E665 Muon Scattering at Low χ_{Bj}

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Muon Scattering at Low x_{Bj}

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ABSTRACT

We present measurements of inelastic muon scattering cross section ratios at very low x_{Bj}. The Xe/D_2 cross section ratio has been measured for x_{Bj} down to 2×10^{-5}. We have also measured the n/p cross section ratio down to $x_{Bj} = 10^{-3}$ and see no significant deviation from unity.

Fermilab experiment E665 [1] is an open geometery muon spectrometer with acceptance for forward tracks down to zero scattering angle. In addition to high precision charged particle acceptance over a large angular range, E665 has an electromagnetic calorimeter consisting of alternating lead plates and proportional chambers. A special Small Angle Trigger (SAT), which uses information on the trajectory of each beam particle to determine an appropriate veto region and reject events with no scatter, allows trigger acceptance at angles down to less than 1 mr. For a typical 490 GeV muon from the FNAL Tevatron muon beam, this angular acceptance implies a lower limit on $x_{Bj} = Q^2/2M\nu$ of order 10^{-5}.

We wish to study inelastic muon scattering cross sections at low x_{Bj}, with emphasis on nuclear A dependence and the difference between n and p. However, at very low $x_{Bj}(< 10^{-3})$ other processes, such as coherent bremsstrahlung from the nucleus and muon-electron elastic scattering, begin to dominate the inclusive muon scattering rate. These processes can be distinguished from true inelastic scatters by their final state event topology. An inelastic scatter will typically have several charged tracks and some electromagnetic energy in the final state in addition to the scattered muon. In contrast, coherent bremsstrahlung will appear in the spectrometer as a scattered muon and an isolated photon-induced shower in the calorimeter. An elastic muon-electron scatter will appear as a scattered muon accompanied by a single negative track and an isolated electron-induced shower in the calorimeter. By eliminating events with low charged particle multiplicities or those with high energy isolated electromagnetic showers, we can eliminate much of the background while retaining most of the true inelastic scatters.

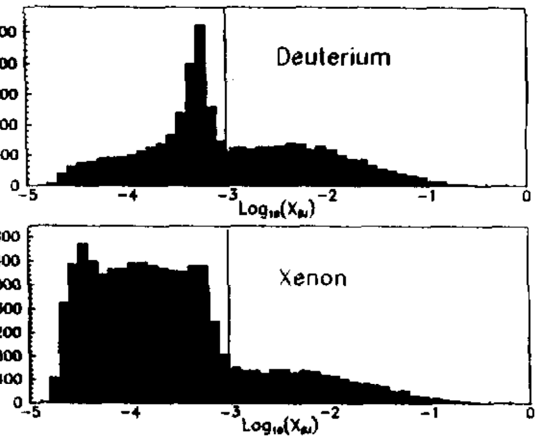

Figure 1: x_{Bj} distributions after kinematic cuts for Deuterium and Xenon.

Nuclear Shadowing

There is considerable interest in the A dependence of inelastic scattering in the very low x_{Bj} region. Shadowing, a depletion of the cross section per nucleon in heavy nuclei as compared to Deuterium, has been observed in previous lepton scattering experiments in the range $0.002 < x_{Bj} < 0.10$ [2],[3] and in real photon scattering [4]. We have extended these measurements to $x_{Bj} \approx 2 \times 10^{-5}$. For a more detailed description of the analysis, see reference [5].

Data were taken with two targets, a 115 cm long liquid Deuterium target and a 113 cm long vessel filled with Xenon gas at 15 atmospheres.

Although the density of the Xenon target was one half that of the Deuterium target, the relative radiation lengths were 1.13 for Xenon and 0.15 for Deuterium. Figure 1 shows the x_{Bj} distributions for the two targets after kinematic cuts. In the Deuterium sample, the muon electron elastic peak at $x_{Bj} = m_e/m_p$ is clearly visible. In the Xenon sample, it is largely obscured by bremsstrahlung events.

All events were required to satisfy the following criteria: $0.01 < Q^2 < 60$ $(\mathrm{GeV/c})^2$, $\nu > 40$ GeV, $|\phi_\mu - \pi| \geq 0.2$, $E_{Beam} > 400$ GeV and $y = \nu/E_{beam} < 0.75$, where the restrictions on Q^2, ν and ϕ ensure good resolution in the scattering parameters and the limit on y removes the region where the bremsstrahlung contamination is largest. After these common kinematic cuts, two independent analyses were performed, one based on information from the electromagnetic calorimeter and the other on charged particle multiplicities.

In the electromagnetic analysis, bremsstrahlung events were removed by requiring that either the energy observed in the electromagnetic calorimeter be less than 0.45ν or that there be no photon candidate coplanar with the incoming and scattered muon momentum vectors. Elastic muon-electron scatters were rejected by an energy dependent proximity cut on the distance from a candidate electron charged track to an electromagnetic cluster.

In the multiplicity analysis, at least two positive or two negative tracks were required in addition to the scattered muon. This eliminates most muon electron scatters and bremsstrahlung events, including those with a photon conversion in the target. At low center of mass energy (low ν, high x_{Bj}) this requirement also removes a significant fraction of the inelastic cross section. Figure 2 compares the x_{Bj} distributions for the two analyses. The Xe/D_2 ratios from the two methods are consistent even in the high x_{Bj} region.

Figure 3 shows the ratio of the cross sections for Xenon and Deuterium from the electromagnetic analysis compared with results from previous experiments [3]. The shadowing effect levels out at x_{Bj} of order 10^{-3} and is consistent with the real photon value as x_{Bj} goes to zero.

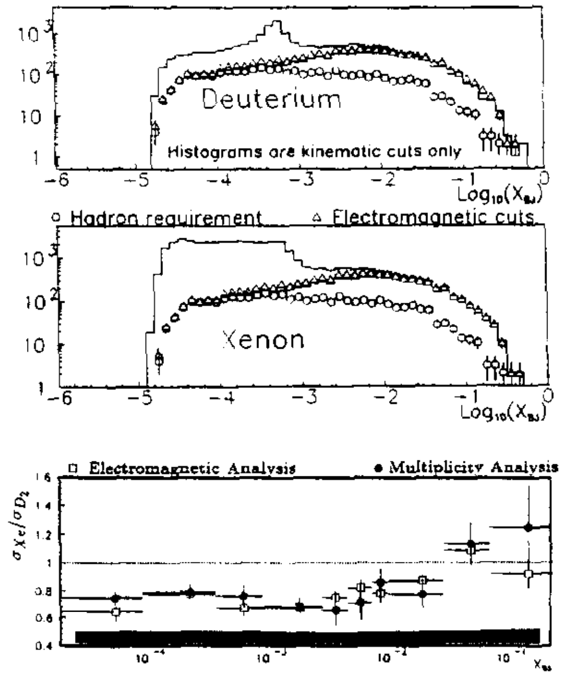

Figure 2: Comparison of two analysis methods; the histogram represents the data with kinematic cuts alone.

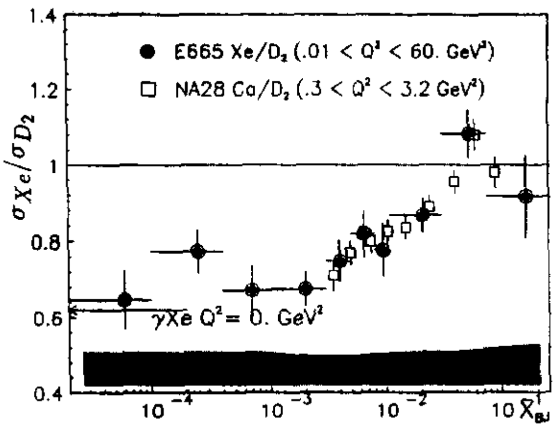

Figure 3: Comparison of Xe/D_2 cross section ratios from the electromagnetic analysis with results from previous experiments. The dark band represents the systematic error

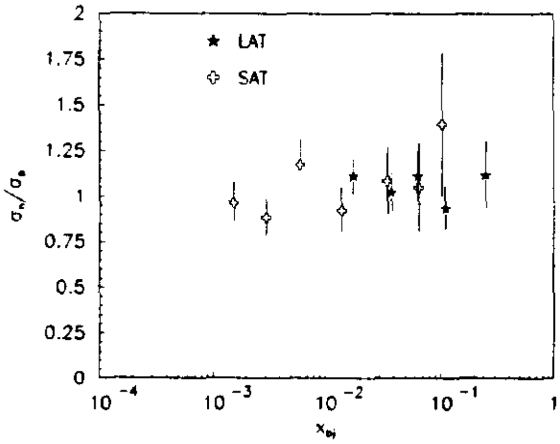

Figure 4: Comparison of n/p ratios for SAT and LAT trigger samples.

Neutron-Proton comparisons

We have also done a more conventional analysis, using kinematic cuts only, of the ratio of neutron and proton structure functions. Data from previous experiments at x_{Bj} above 0.004 have been used to evaluate the Gottfried [6] sum:

$$S = \int_0^1 \left(F_2{}^p - F_2{}^n \right) \frac{dx}{x}.$$

The parton model prediction for this sum is 1/3. The most accurate measurement, by the NMC collaboration at CERN [7], is $S = 0.240 \pm 0.016$. This includes an extrapolation from x_{Bj} of 0.004 to 0.0. The deviation of the measured sum from the parton model prediction might be explained by a depletion in the n/p ratio for x_{Bj} below 0.004. We have used our Small Angle Trigger (SAT) to extend the measurement of the ratio of neutron and proton cross sections to $x_{Bj} = 10^{-3}$ [8]. In Figure 4, E665 data taken using the SAT with $Q^2 > 0.1$ (GeV/c)^2 are compared with data taken using the more conventional Large Angle Trigger (LAT) with $Q^2 > 4$ (GeV/c)^2. The errors shown are statistical only, the estimated systematic error is 6%. Within the statistics, these values are consistent with the NMC measurement in the low x_{Bj} region. There is no evidence of a large depletion in the ratio at very low x_{Bj} needed to bring the measured sum into agreement with the parton model prediction.

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